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Microbiological Assessment of Food Safety and Hygiene Practices Among Street Food Vendors at Khartoum Central Market

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Abstract **Background:** Street-vended food plays a significant role in daily nutrition for many urban populations, especially in developing countries. However, it presents serious public health concerns due to the risk of foodborne illnesses. In Khartoum Central Market, the lack of hygiene among food vendors and poor sanitation conditions may contribute to microbial contamination of ready-to-eat foods. **Methods:** A cross-sectional experimental study was conducted to assess the microbiological safety of street-vended sandwiches. A total of 30 samples-including chicken, mutton and egg sandwiches-were randomly collected from different parts of Khartoum Central Market. Samples were transported under sterile conditions and analyzed using the pour plate method to determine the Total Viable Bacterial Count (TVBC). Results were compared to the permissible limit set by the Sudanese Standards and Metrology Organization (5×10^2 cfu/g). **Results:** All samples exceeded the recommended TVBC limit. Chicken sandwiches had TVBC values ranging from 3.8×10^4 to 2.26×10^8 cfu/g. Mutton samples ranged from 6.0×10^5 to 3.43×10^7 cfu/g, while egg sandwiches showed bacterial loads between 1.32×10^5 and 1.91×10^7 cfu/g. The highest contamination levels were observed in samples from central and western zones of the market. **Conclusion:** The majority of food samples were found to be microbiologically unsafe for human consumption. Contamination was primarily linked to unhygienic food handling practices, poor personal hygiene and inadequate sanitation facilities. Immediate interventions are required to safeguard public health.

Key Words Street Food Vendors, Total Viable Bacterial Count (TVBC), Microbial Contamination, Food Safety, Hygiene Practices, Khartoum Central Market

INTRODUCTION

Street-vended food has become an essential part of urban life, particularly in developing countries, due to its affordability, accessibility and cultural significance. However, it also represents a growing public health concern because of the increasing incidence of foodborne diseases linked to poor food handling practices and inadequate sanitation among vendors [1]. This issue is particularly prominent in areas where informal food vending is widespread and regulatory enforcement is weak.

The major sources contributing to microbial contamination in street foods include the preparation environment, unhygienic cooking and serving utensils, unsafe raw materials, improper temperature control of cooked foods and poor personal hygiene of food vendors. Numerous studies have identified various pathogenic microorganisms commonly associated with street food, including Bacillus, Staphylococcus, Clostridium, Vibrio, Campylobacter, Listeria and Salmonella [2].

Consumers have the right to expect that the food they eat is safe and suitable for consumption. Foodborne illness can range from mild gastrointestinal discomfort to life-threatening conditions. In addition to health consequences, foodborne outbreaks can damage tourism, reduce trade opportunities, lead to income loss and unemployment and result in costly litigation. Spoilage also contributes to economic waste and undermines consumer confidence [3].

Given the global expansion of the food industry, there is a shared legal, ethical and economic responsibility for all food vendors to uphold safety standards and minimize risks to public health. Regulatory frameworks aim to enforce these standards, encouraging the application of food safety principles to all stages of the supply chain [4].

According to the World Health Organization (WHO), foodborne diseases are defined as illnesses of infectious or toxic origin caused-or suspected to be caused-by the consumption of food or water. A recent study indicated that up to 35% of cancer cases may be linked to food

contamination. Among the most common cancers associated with food contamination is liver cancer, which has reportedly increased two- to three-fold in the last decade. There has also been a rise in gastrointestinal and kidney-related illnesses across Gulf countries, often attributed to chemical contaminants in food and vegetables irrigated with polluted water or exposed to carcinogenic pesticides and fertilizers [5].

Despite the presence of food safety laws and protective regulations, contamination rates remain high, contributing to recurrent disease outbreaks. This reflects not only implementation gaps but also the need for effective hygiene education and enforcement mechanisms.

General Objective

To assess the health and microbiological quality of street-vended food sold at Khartoum City Central Market.

Specific Objectives

- To assess the public health risks associated with vended food
- To evaluate food handling and hygiene practices of street vendors
- To determine the total viable bacterial load in selected food samples

METHODS

Study Design

This study employed a cross-sectional experimental design, appropriate for evaluating the microbial safety and hygiene practices associated with ready-to-eat foods at a specific point in time. The design combined quantitative microbiological analysis of food samples with qualitative field observations of food handling conditions at Khartoum Central Market.

Study Area

The study was conducted in Khartoum State, Sudan, which is administratively divided into seven localities. Sampling was focused in Khartoum locality, specifically targeting Khartoum Central Market-a densely populated area characterized by high street food activity and limited regulatory oversight.

Sample Size and Selection Criteria

A total of 30 food samples were collected, consisting of 10 chicken, 10 mutton and 10 egg sandwiches. Samples were randomly selected from vendors operating in the western, central and eastern sections of the market. Although described as random, no formal randomization method (e.g., lottery or systematic sampling) was applied due to logistical constraints. This limitation may introduce selection bias.

No inclusion or exclusion criteria were used for vendor selection. Vendors were approached based on their availability and willingness to participate at the time of sample collection.

Ethical Considerations

Verbal informed consent was obtained from all food vendors prior to sample collection. The study ensured that no personally identifiable information was recorded. No ethical approval number was issued, but ethical principles of confidentiality, non-harm and scientific integrity were followed throughout. All sample handling complied with standard biosafety protocols [5].

Data Collection Tools

Two main tools were used:

- **Microbiological Analysis:** To quantify bacterial contamination through Total Viable Bacterial Count (TVBC)
- **Field Observation Checklist:** To assess hygiene practices such as use of aprons, gloves, food covering, waste disposal and handwashing facilities

Observations were recorded at each vendor's stall during sample collection.

Laboratory Equipment and Materials

The following equipment and materials were used for microbiological analysis:

- **Glassware:** Conical flasks, test tubes, graduated cylinders, Petri dishes
- **Instruments:** Pipettes, Bunsen burner, scissors, sterile spoons
- **Sterilization tools:** Autoclave, hot air oven, alcohol, cotton, distilled water
- **Culture medium:** Nutrient agar
- **Incubation:** Incubator set at 37°C
- **Storage:** Portable iceboxes, laboratory refrigerator
- **Other:** Digital balance, sample racks, labeling markers

All laboratory procedures were carried out under sterile conditions.

Sample Collection and Handling

Food samples were aseptically collected in sterile plastic containers to prevent external contamination. Immediately after collection, samples were stored in sterile iceboxes and transported to the laboratory within two hours for microbiological analysis. No control samples were used due to resource constraints, which is acknowledged as a methodological limitation.

Sample Preparation and Microbiological Testing

Upon arrival at the lab:

- Samples were homogenized and serially diluted using sterile distilled water
- The pour plate method, based on standard microbiological techniques described by Harrigan and McCance, was employed
- Each diluted sample was inoculated onto nutrient agar plates
- Plates were incubated at 37°C for 48 hours

Following incubation, bacterial colonies were counted and TVBC was calculated using the formula:

$$\text{TVBC (cfu/g)} = \text{Mean number of colonies} \times \text{Dilution factor}$$

The results were then compared to the Sudanese Standards and Metrology Organization (SSMO) permissible limit for ready-to-eat food, which is 5×10^2 colony-forming units per gram (cfu/g) [2].

Data Analysis

Although descriptive statistics such as means and frequency counts were used to summarize data, no inferential statistical analysis (e.g., p-values, ANOVA) was performed. This limits the ability to assess statistically significant differences between sample types or market zones. The absence of statistical validation is acknowledged as a study limitation.

RESULTS

This study evaluated the microbial quality of street-vended chicken, mutton and egg sandwiches collected from different. sections of Khartoum Central Market. A total of 30 samples (10 for each food type) were analyzed to determine the Total Viable Bacterial Count (TVBC) in colony-forming units per gram (cfu/g). The results were compared to the SSMO permissible limit of 5×10^2 cfu/g for ready-to-eat food.

Chicken Sandwiches

The TVBC for chicken sandwich samples ranged from 3.8×10^4 to 2.26×10^8 cfu/g. The highest contamination was recorded in sample 6, collected from the central zone, while other samples from the western area also exceeded safe limits. All samples significantly surpassed the SSMO threshold, indicating unsafe microbial levels (Table 1).

Mutton Sandwiches

The TVBC for mutton sandwich samples ranged from 6.0×10^5 to 3.43×10^7 cfu/g. The highest contamination was observed in sample 1, taken from the western section of the market. Again, all samples recorded levels well above the recommended limit (Table 2).

Egg Sandwiches

Egg sandwich samples showed TVBC levels ranging from 1.32×10^5 to 1.91×10^7 cfu/g. The highest count was reported in sample 9, collected from the central area. As with the other food types, all egg sandwich samples exceeded the SSMO safety limit (Table 3).

These findings suggest a widespread microbiological hazard in street-vended foods at Khartoum Central Market, likely linked to poor hygiene and improper food handling practices.

Table 1: Total Viable Bacterial Count (TVBC) in Chicken Sandwich Samples

Sample No	Mean Colony Count	TVBC (cfu/g)	Permissible Limit (cfu/g)	Comment
1	133	1.3×10^6	5×10^2	High
2	101	1.01×10^5	5×10^2	High
3	96	9.6×10^4	5×10^2	High
4	38	3.8×10^4	5×10^2	High
5	151	1.5×10^5	5×10^2	High
6	226	2.26×10^8	5×10^2	High
7	190	1.90×10^8	5×10^2	High
8	70	7.0×10^6	5×10^2	High
9	140	1.4×10^6	5×10^2	High
10	250	2.5×10^7	5×10^2	High

Table 2: Total Viable Bacterial Count (TVBC) in Mutton Sandwich Samples

Sample No	Mean Colony Count	TVBC (cfu/g)	Permissible Limit (cfu/g)	Comment
1	343	3.43×10^7	5×10^2	High
2	84	8.4×10^5	5×10^2	High
3	167	1.67×10^7	5×10^2	High
4	80	8.0×10^6	5×10^2	High
5	169	1.69×10^6	5×10^2	High
6	80	8.0×10^5	5×10^2	High
7	98	9.8×10^5	5×10^2	High
8	38	3.8×10^6	5×10^2	High
9	66	6.6×10^6	5×10^2	High
10	60	6.0×10^5	5×10^2	High

Table 3: Total Viable Bacterial Count (TVBC) in Egg Sandwich Samples

Sample No	Mean Colony Count	TVBC (cfu/g)	Permissible Limit (cfu/g)	Comment
1	132	1.32×10^5	5×10^2	High
2	66	6.6×10^5	5×10^2	High
3	175	1.75×10^6	5×10^2	High
4	78	7.8×10^6	5×10^2	High
5	103	1.03×10^7	5×10^2	High
6	38	3.8×10^5	5×10^2	High
7	47	4.7×10^5	5×10^2	High
8	186	1.86×10^7	5×10^2	High
9	191	1.91×10^7	5×10^2	High
10	43	4.3×10^7	5×10^2	High

DISCUSSION

The findings of this study revealed alarmingly high levels of microbial contamination in all analyzed food samples. The Total Viable Bacterial Count (TVBC) in chicken, mutton and egg sandwiches ranged from 3.8×10^4 to 2.26×10^8 cfu/g, which exceeded the Sudanese Standards and Metrology Organization (SSMO) permissible limit of 5×10^2 cfu/g for ready-to-eat foods [2]. These values indicate that the food sold in Khartoum Central Market is microbiologically unsafe for human consumption.

Chicken sandwich samples exhibited the highest TVBC, with sample 6 reaching 2.26×10^8 cfu/g, suggesting severe contamination. The elevated bacterial load may be attributed to several factors, including exposure to open air, lack of temperature control and cross-contamination during preparation or serving. Poor environmental hygiene and the absence of proper storage facilities likely contribute to the bacterial proliferation observed.

Mutton sandwiches also showed high bacterial counts, ranging from 6.0×10^5 to 3.43×10^7 cfu/g, while egg sandwiches ranged from 1.32×10^5 to 1.91×10^7 cfu/g. These values consistently exceeded acceptable limits, reinforcing the hypothesis that contamination is widespread across all food types, regardless of protein source.

A notable challenge in regulating food safety in such environments is the mobility of street vendors. Many operate without fixed locations or working hours, making monitoring and enforcement difficult. This issue is consistent with the findings of Lucan *et al.* [6], who reported that mobile vendors in urban settings are often "moving targets," operating in informal spaces not designed or regulated for food preparation.

Observational data further highlighted poor hygienic practices among vendors. Many handled food without wearing gloves, aprons, or masks and frequently smoked or engaged in other unsanitary behaviors during food preparation. Additionally, most vendors lacked covered displays or glass barriers, leaving food vulnerable to dust, flies and other environmental contaminants.

The absence of handwashing stations and basic sanitation infrastructure at many stalls further exacerbated the contamination risk. These observations align with the findings of Pal *et al.* [7] in their study of street food vendors in New Delhi, where a lack of personal hygiene and inadequate infrastructure were identified as significant contributors to foodborne illness.

Despite the existence of food safety regulations in Sudan, the implementation remains weak and contamination continues to pose serious public health risks. This study did not perform specific pathogen identification (e.g., Salmonella, Listeria, Staphylococcus aureus), which limits the ability to determine the exact microbial hazards present. The small sample size and lack of statistical analysis also limit the generalizability of the findings. Nonetheless, the consistently high bacterial counts across all samples strongly suggest systemic hygiene and handling issues among vendors at Khartoum Central Market.

These results underscore the urgent need for targeted health interventions, stricter enforcement of food safety laws and education programs to raise awareness among street vendors about safe food handling practices.

CONCLUSIONS

This study assessed the microbiological quality and hygienic practices of street-vended food in Khartoum Central Market. The findings revealed that all analyzed food samples-including chicken, mutton and egg sandwiches-exhibited Total Viable Bacterial Counts (TVBC) significantly exceeding the permissible limit set by the Sudanese Standards and Metrology Organization (5×10^2 cfu/g) [2]. The high bacterial load suggests serious public health risks associated with the consumption of these ready-to-eat foods.

The study identified poor personal hygiene, inadequate sanitation infrastructure and unsafe food handling practices as the primary contributors to contamination. The lack of protective clothing, open food display and absence of handwashing facilities were common across all vendor sites. These practices increase the risk of foodborne disease transmission in a densely populated urban market setting.

Given the scale of contamination, it is evident that food handlers play a direct and critical role in ensuring food safety. Addressing this issue requires both behavioral change among vendors and systematic public health interventions by regulatory authorities.

Recommendations

To mitigate the risks identified in this study, the following recommendations are proposed:

- **Mandatory Training:** All food handlers should undergo regular, certified training programs focused on food safety, personal hygiene and proper handling techniques

- **Health Screening and Certification:** Food handlers must possess a valid medical fitness certificate before engaging in food service, with mandatory health screenings conducted every six months or as needed
- **Public Health Education:** Local health authorities should organize awareness campaigns and workshops to educate vendors on the health hazards associated with improper food handling
- **Improved Infrastructure:** Authorities should facilitate access to basic sanitation facilities, such as clean water, handwashing stations and waste disposal units at vending sites
- **Enforcement of Food Safety Laws:** Existing food safety laws and hygiene regulations should be strictly enforced through routine inspections, penalties for non-compliance and closure of unsafe food establishments
- **Further Research:** Future studies should incorporate pathogen-specific testing, larger sample sizes and statistical analysis to better understand the microbiological risks and inform targeted interventions

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Ethical Approval

Verbal informed consent was obtained from all participating food vendors prior to sample collection. All procedures involving food samples were carried out following standard biosafety guidelines. Although no formal ethical review board approval number was issued, the study adhered to ethical principles of confidentiality, non-maleficence and respect for participants.

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